Spacewalking

Background

This problem applies mathematical principles in NASA's human spaceflight.

The International Space Station (ISS) Mission Control Center (MCC) uses some of the most sophisticated technology and communication equipment in the world. Teams of highly qualified engineers, scientists, doctors, and technicians (known as flight controllers) monitor the systems and activities aboard the ISS. They work together as a powerful team, spending many hours performing critical simulations as they prepare to support each mission and crew during both normal operations and any unexpected events. Aspects of spacewalks performed from the ISS are monitored by the Extra-Vehicular Activities (EVA) Officer. This flight controller monitors the technical operation of the spacesuits and the activities to be carried out before, during, and after a spacewalk.

The pressurized spacesuit worn by astronauts during a spacewalk is officially known as an Extra-vehicular Mobility Unit (EMU). An EMU is worn anytime a crewmember is required to step outside of a pressurized vehicle (i.e., the ISS) to work in the vacuum of space. The key features of the EMU are breathable air, habitable pressure, temperature control, and protection from the harsh space environment.

Suppose an astronaut were to leave a pressurized vehicle without wearing a pressurized suit. Without oxygen, he or she would quickly lose consciousness. Without pressurization, the astronaut would not be expected to survive longer than fifteen seconds. Temperature fluctuations in orbit are caused by the rising and setting of the sun, and temperatures can fluctuate from 120^{o} C (248^{o} F) in sunlight to -100^{o} C (-148^{o} F) in darkness, cycling every forty-five minutes. This means that, during an EVA that lasts for hours, an unprotected person would experience extreme temperatures, potentially causing his or her own body fluids to boil from the heat or freeze from the cold. In addition to the lack of oxygen and pressurization, and exposure to fluctuating temperatures, an unsuited individual would also be exposed to radiation and cosmic rays, and could risk fatal bodily injury from orbiting space debris (e.g. micrometeoroids) moving at high rates of speed.

Figure 1: An astronaut on the robotic arm of the ISS

Figure 2: An astronaut on EVA

Along with protecting humans on spacewalks, the EMU also allows astronauts to move around with a comfortable range of motion for arms and legs, provides good visibility, and allows communication with the crew and the MCC. Like a personal spaceship, the EMU allows crewmembers to perform scheduled activities and planned spacewalks for up to seven hours at a time.

Instructional Objectives

You will

- write a regression equation and interpret the meaning of the slope and *y*-intercepts in the context of the problem;
- make predictions based on the correct mathematical models; and
- solve linear equations.

Directions: On the TI-Nspire™ handheld, open the document, Alg-ST_Spacewalking. Complete the embedded questions on pages 1.2–1.4.

1.2 Imagine that you are an astronaut. What would you need to survive and successfully complete a spacewalk?

1.3 What would happen to your oxygen supply as you perform a spacewalk?

1.4 Explain why your oxygen usage might be different from another astronaut's oxygen usage during a spacewalk.

Directions: Read the problem set up on page 1.5. Answer questions 1.7–1.13 in your group. Discuss answers to ensure everyone understands and agrees on the solutions. Round all answers to three decimal places, and label with the appropriate units.

Problem

The EVA Officer is preparing for an upcoming mission in which two astronauts will install solar panels on the International Space Station (ISS). The spacewalk will last about seven hours. In order to ensure that the first astronaut (Astronaut A) can complete the mission with a normal oxygen supply, the EVA Officer is reviewing Astronaut A's oxygen usage data from a previous EVA (as shown in Table 1).

Oxygen usage data is measured by oxygen (O_2) tank pressure using pounds per square inch (psi), and EVA duration (or time) data is measured in hours (hrs).

Table 1: Astronaut A's oxygen usage data during previous EVA

O_2 Tank Pressure (psi)	**EVA Time (hrs)**	**O_2 Tank Pressure (psi)** *(continued)*	**EVA Time (hrs)** *(continued)*
880.000	0.033	576.728	3.300
880.000	0.100	565.714	3.400
868.718	0.200	554.701	3.500
857.973	0.300	545.031	3.600
849.109	0.400	536.972	3.700
841.319	0.500	529.988	3.800
828.156	0.600	523.004	3.900
817.143	0.700	516.020	4.000
803.443	0.800	507.961	4.100
791.624	0.900	499.365	4.200
780.611	1.033	492.918	4.300
776.044	1.100	484.591	4.400
766.911	1.200	476.264	4.500
750.000	1.300	467.937	4.600
742.198	1.500	457.998	4.700
730.916	1.600	451.551	4.800
706.203	1.800	444.567	4.900
698.144	1.900	435.971	5.000
689.817	2.000	427.912	5.100
682.564	2.100	421.465	5.200
674.506	2.200	411.526	5.300
656.777	2.400	405.885	5.400
647.106	2.500	399.438	5.500
638.510	2.600	391.111	5.600
629.377	2.700	381.172	5.700
621.050	2.800	372.576	5.800
612.723	2.900	363.712	5.900
604.664	3.000	354.310	6.000

1.7 Analyze the data on page. What type of correlation would you predict best fits this data?

- o linear
- o quadratic
- o cubic

1.8 On page 1.9, plot the oxygen tank pressure (psi) vs. the time (hrs). Determine an appropriate mathematical model to fit the data.

1.10 Interpret the slope and y-intercept of your model in the context of the problem.

1.11 Use the model to determine if Astronaut A can perform a seven-hour spacewalk before depleting his or her oxygen.

1.12 Determine the *x*-intercept, and explain what it means in this scenario.

1.13 What type of correlation between time and oxygen usage is displayed by the plotted data?

Directions: Read the problem set up on page 2.1. Answer question 2.3 in your group. Discuss answers to ensure everyone understands and agrees on the solutions.

Astronaut B will be accompanying Astronaut A to assist with the solar panel installation. The EVA Officer is evaluating previous oxygen usage data for Astronaut B (as shown in Table 2).

Table 2: Astronaut B's oxygen usage during a previous EVA

O_2 Tank Pressure (psi)	EVA Time (hrs)	O_2 Tank Pressure (psi) *(continued)*	EVA Time (hrs) *(continued)*
853.138	0.100	531.600	3.300
838.633	0.200	520.049	3.400
826.007	0.300	515.751	3.500
812.845	0.400	508.767	3.600
801.294	0.500	501.514	3.700
790.818	0.600	489.695	3.800
778.462	0.700	479.756	3.900
763.956	0.800	462.564	4.000
758.315	0.900	456.923	4.100
753.480	1.000	449.939	4.200
749.719	1.100	437.045	4.300
744.078	1.200	425.226	4.400
735.214	1.300	414.481	4.500
720.977	1.500	402.393	4.600
715.067	1.600	390.574	4.700
707.546	1.700	381.441	4.800
703.785	1.800	359.145	5.000
696.264	1.900	338.999	5.200
687.668	2.000	327.985	5.300
680.684	2.100	318.046	5.400
652.210	2.200	310.256	5.500
635.018	2.300	301.661	5.600
624.811	2.400	290.110	5.700
611.917	2.500	272.918	5.900
597.949	2.600	263.785	6.000
588.816	2.700	255.727	6.100
554.432	3.100	241.221	6.200
543.150	3.200	226.716	6.300

2.3 What is different about the oxygen usage data of Astronaut B?

Directions: Complete questions 2.4–3.3 independently. Round all answers to three decimal places, and label with the appropriate units.

2.4 On page 2.5, create a scatter plot for Astronaut B's oxygen usage vs. time and determine the mathematical model that fits the data.

2.6 What can be determined from the slope of Astronaut B's model, when comparing the slopes from both models?

Three hours into the spacewalk, Astronaut B has become exhausted. Since Astronaut A is using less oxygen than Astronaut B, Astronaut A is asked to perform the more strenuous EVA tasks. The Extra-Vehicular Activities (EVA) Officer recommends that the two astronauts switch duties.

2.8 How much oxygen tank pressure can we predict that each astronaut has left at this point?

Astronaut A *Astronaut B*

2.9 Write two new equations to represent the oxygen tank pressure for each astronaut after switching roles. Astronaut B now has a lighter workload, and is using oxygen at a rate of 87.970 psi/hr. Astronaut A now has the more strenuous workload, and is using oxygen at a rate of 99.774 psi/hr. Use p to represent oxygen tank pressure (in psi) and t to represent EVA time (in hrs).

Astronaut A:

Astronaut B:

2.11 The EVA Officer has recommended that the spacewalk be aborted if either astronaut reaches an oxygen tank pressure of 150 psi before the mission is complete. If four more hours are required to complete the EVA, will the astronauts be able to finish the spacewalk?

Astronaut A *Astronaut B*

Pre-AP Extension

3.2 In Statistics, the actual value minus the predicted value is called a residual. What is the oxygen tank pressure residual when Astronaut A has been on the spacewalk for five hours?

3.3 Is this an overestimate or an underestimate? Explain.